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TRANSACTIONS

OF THE

ILLUMINATING ENGINEERING SOCIETY

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VOLUME III—No. 1
JANUARY, 1938

32 VICTORIA STREET
LONDON SW1

NOTES ON RECENT MEETINGS AND EVENTS

General Meeting in London.

A meeting of the Society was held in the Lecture Theatre of the Institution of Mechanical Engineers (Storey's Gate, St. James's Park, London, S.W.1) on Tuesday, December 14. The chair was taken by the President (Dr. S. English).

The minutes of the last meeting were taken as read, and the hon. secretary mentioned that lists of new applicants for membership and of formally declared members were available for inspection.

The President then called upon Mr. Dean Chandler to present his paper entitled "Incandescence Gas Lighting," which was illustrated by lantern slides and demonstrations. On the motion of the President a vote of thanks was accorded to the author for his interesting paper. Mr. A. Cunnington, Mr. F. C. Smith, Mr. K. F. Sawyer, Mr. J. S. Dow, and Dr. S. English took part in the ensuing discussion.

Sectional Meetings in London.

Industrial Lighting Section.

A visit was arranged to the printing works of Messrs. Waterlow and Sons, Park Royal, on December 7. Members assembled at the factory at 6.30 p.m., when Mr. L. M. Tye gave a brief description of the chief features of the lighting, after which the party was conducted round the works by the manager. An informal discussion subsequently took place in the Park Royal Hotel, where Mr. Tye replied to a number of inquiries in regard to the installation just visited. In the absence of the chairman (Mr. R. O. Ackerley), Mr. P. S. Barton presided.

Decorative Lighting Section.

The second meeting of the above section took place in the Henry Jarvis Hall of the Royal Institute of British Architects on December 10, when Mr. A. W. Beuttell presided. Addresses were delivered reviewing lighting problems from the standpoint of the architect by Mr. Oliver P. Bernard ("Problems in Decorative Lighting"), Mr. Lawrence M. Gotch ("Illumination Problems of a G.P.A."), and Mr. Albert D. Millar ("The Application of Lighting to Retail Stores"). The discussion was opened by Mr. R. O. Ackerley, and a series of lantern slides, illustrating distinctive lighting problems involving decorative effect, were shown by Mr. R. O. Sutherland and Mr. E. Stroud.

Meetings of Local Centres.

Irish Free State.

At a meeting held in Dublin, on December 7, an address was delivered by Dr. S. English on "Glassware in Relation to Illuminating Engineering."

Scotland.

At a meeting held in Glasgow, on December 8, over which Mr. Alex. Lindsay presided, an address on "Electric Lamps: Their Specification and Testing" was delivered by Mr. T. M. Lappin. In the subsequent discussion Mr. E. J. Stewart, Mr. J. Ward, Mr. S. Kates. Mr. H. E. de Weerdt, and Mr. M. W. Hime took part.

North Midland Area.

Mr. R. Gillespie Williams delivered an address on "Decorative and Colour Lighting," at a meeting held in Leeds on December 13.

North-Western Area.

At a meeting held in Manchester, on December 13, over which Mr. R. C. Hawkins presided, an address on "The Measurement of Daylight" was delivered by Mr. John Swarbrick.

Forthcoming General Meeting.

The next general meeting will be held in the Hall of the Institution of Mechanical Engineers (Storey's Gate, London, S.W.1), at 6.30 p.m., on Tuesday, February 8. A discussion on the final report of the M.O.T. Committee on Street Lighting will be opened by Dr. J. W. T. Walsh, and a film showing methods of testing visibility in the streets will be shown.

The Annual Dinner.

The attention of members is specially drawn to the annual dinner, to take place at the Trocadero Restaurant (London, W.1.), on Tuesday, March 15.

Tickets (15s. each, exclusive of wine) may be obtained from the hon. secretary, to whom application should preferably be made *before February* 28.

Applicants for Membership.

At the general meeting of the Society, held on December 14, 1937, the names of the following applicants for membership were presented:—

Elections Pending.

CORPORATE MEMBERS:—

Dunn, E	The E.G.L. Company, Ltd., Great George Street, LEEDS.
Fradd, D. A.	16, Rokeby Gardens, Woodford Green, ESSEX.
Hatton, K. N.	The British Thomson-Houston Co., Ltd., Crown House, Aldwych, LONDON, W.C.2.
Hobbs, W. A. G.	51, Jevington Way, Lee, LONDON, S.E.12.
Mountain, G.	43, York Place, LEEDS.
Philpot, P. C.	38, Montbelle Road, New Eltham, LONDON, S.E.9.
Robinson, W.	St. Rouan's, 160, Lordship Road, LONDON, N.16.
Russell, D. T.	"Grasmere," The Avenue, Bushey, HERTS.
Sawyer, E. B.	299, Staines Road, Twickenham, MIDDLESEX.
Taylor, A. C.	Montrose House, 8, Craig Park, GLASGOW, E.1.
Watson, A. H.	Coombe Littleton Crescent, Harrow, MIDDLESEX.
White, W. J.	17, Hillfield Park, Winchmore Hill, LONDON, N.21.

COUNTRY MEMBERS:—

Anderson, R. J.	Pelletstown House, Phibsborough, DUBLIN.
Bailey, S.	7, Cumerland Street, Dun-Laoghaire, Co. DUBLIN.

Elections Completed.

At this meeting the names of those announced on November 16, which were published in the issue of the *Transactions* (Vol. II., No. 12, December, 1937, p. 158), were presented again, and these applicants were formally declared members of the Society.

LIGHTING FOR SPECIAL INDUSTRIAL PURPOSES

By W. R. STEVENS, B.Sc. *(Member)*, and S. ANDERSON, B.Sc.

(Paper read on Tuesday, November 16th, 1937.)

Among the many industrial lighting problems which occur from time to time, are some which are of considerable general interest because they appear frequently. These problems are being solved gradually by the introduction of new lighting fittings and light sources and by new methods of attack on the problems involved.

In this paper it is intended to discuss some of the types of installation which are passing from the problem stage into one of simple application of normal lighting technique and the development of special fittings for these applications.

It is convenient to consider two general types of situation:—

(a) Those requiring special mechanical features in the fittings design.

(b) Those requiring special optical arrangements and light sources.

Section (a) includes the lighting of spraying booths and similar situations where the atmosphere is laden with explosive or inflammable materials, so that flameproof fittings are required. Equipment for use in corrosive atmospheres, such as acids, alkalis, and sea spray, is also discussed.

Section (b) will cover such problems as the examination of polished surfaces in connection with tin and chromium plate inspection, and the provision of artificial daylight for the colour matching of cloth, and furs, and for use in industries where the critical examination of colours is involved.

(a) Installations with fittings having special mechanical features.

Situations where explosive or inflammable materials are used.

In situations of this type, ordinary lighting fittings are unsuitable owing to the danger of fire or explosion due to the surface temperature of the lamp, the risk of lamp breakage while on circuit, or the possibility of electric spark at the lamp contacts or elsewhere. Designs which are termed "dust-tight" or "water-tight" are but little better than the ordinary open or enclosed type of fitting, for they permit the ingress and accumulation of the dangerous vapour in explosive concentrations, and this, on ignition, may disrupt some part of the fitting or packing and thus communicate the flame to the outer atmosphere. In addition, the surface temperature of these fittings is often above that considered safe with the more dangerous materials.

The type and size of the enclosure where the inflammable material exists varies from a small booth or container to a large department, but, in general, one of three alternative methods of lighting may be adopted.

(a) The area may be illuminated by means of floodlights or other non-flameproof fittings situated outside and throwing light in through windows in the roof or side walls.

(b) Fittings of a non-flameproof type may be used just outside a partially enclosed dangerous area.

(c) Fittings of special flameproof design may be used within the area.

Method (a) (Fig. 1) has been found satisfactory for all sizes of enclosure, but is particularly suitable for the larger ones, since it permits the use of ordinary fittings of large light output and high efficiency. It has the disadvantage that the useful illumination is entirely dependent on transmission through windows or glazed roof-lights, and the illumination falls off rapidly unless these are cleaned very frequently. In the case of fittings above the roof, the provision of cat walks or other permanent facilities for access are practically essential. Owing to the high mounting and losses associated with projection through the glazing, the coefficient of utilisation tends to be low, and the ratio of illuminations on vertical and horizontals may be poor unless the shop is very large in relation to its height or supplementary lighting from the sides is included. Vertical plane illumination is particularly important in paint shops, since frequently the majority of the surfaces to be treated are vertical or nearly vertical.

Fig. 1. A cellulose paint shop illuminated by high pressure mercury vapour lamps housed in dispersive reflectors situated outside the roof glazing.

Method (b) (Fig. 2) has been used where a booth is provided with an efficient air extraction system installed so that the dangerous vapour is drawn away from the open side where the fittings are located. Usually two fittings of an enclosed wide angle floodlight type are employed for each booth. These are arranged to project light into the booth diagonally

from the upper corners of the open side so that the operator is normally facing in the direction of the incident light which reaches the sprayed surface

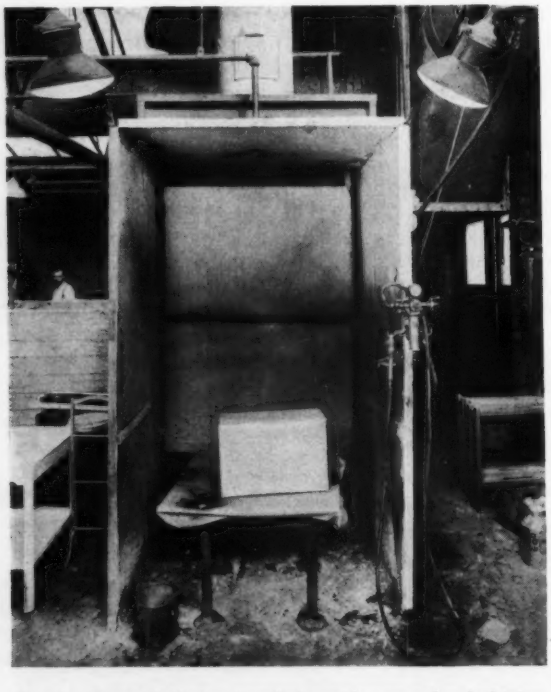

Fig. 2. Dust-tight fittings installed outside a spray booth shining over the operative's shoulder give satisfactory illumination without the necessity of the fittings being put in the explosive atmosphere.

from each side of him. Such a system is efficient and easily maintained at full intensity, but it is inclined to be too directional, particularly if the booth is narrow. While whitened inside walls improve the illumination on surfaces which are oblique to the direction of the primary illumination, if the sprayed colour is dark the spilled paint must be washed off or the walls re-whitened frequently in order to maintain a high reflection factor.

A suitable enclosed type of fitting made in glass and porcelain with a silvered parabolic reflecting surface and internally frosted diffusing front, the whole being mounted on an adjustable bracket arranged for conduit fixing, is illustrated. (Fig. 3.) Two such fittings equipped with 200-watt general service lamps provide an illumination of the order of 80-100 foot-candles over an area of about 4 ft. square at a distance of 7 ft., and the whole area covered is considerably larger than this. Parabolic angle reflectors fitted with cover glasses are also suitable, but do not provide such a high illumination on the area occupied by the work for the same lamp wattage.

Method (c) (Fig. 4) still remains the only possible one in some situations and necessitates the use of special fittings in which (1) it is impossible for an external vapour or dust to enter the fitting and accumulate sufficiently to give an ignitable mixture; or

Fig. 3. Enclosed silvered glass floodlight fitting with adjustable bracket.

(2) it is impossible for internal ignition to influence the outside atmosphere, and (3) the temperature of the outer surfaces is below that required to cause ignition on contact with the dangerous material. The first alternative has been found impractical under service conditions owing to the high cost, complicated construction, and the difficulty of ensuring that such a fitting is safely re-assembled after it has been opened for maintenance or lamp replacement.

It is, however, found practicable to make a fitting which, though not perfectly sealed against the ingress of inflammable vapours, is sufficiently robust to withstand internal explosion and to prevent the passage of a flame to the outside. To achieve this result all joints in the fitting are constructed in the form of large flanges with machined surfaces which results in a small air gap (of the order of 0.01 inch). A flame caused by an explosion in the fitting will tend to pass through the gap between the flanges and in

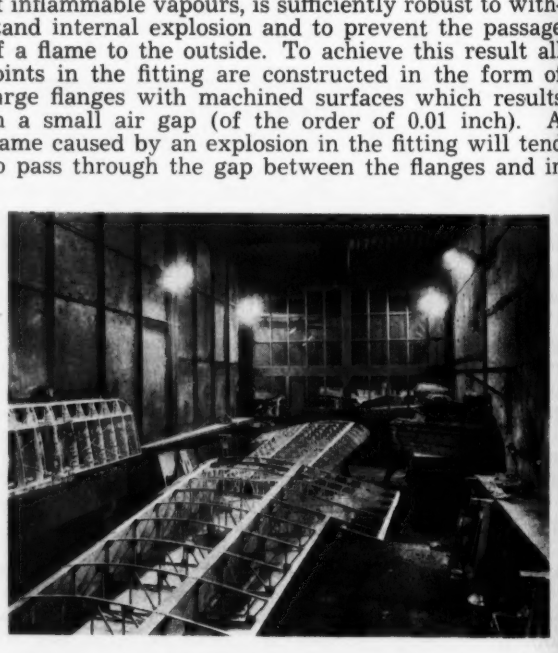

Fig. 4. A cellulose spraying booth illuminated by means of flameproof lighting fittings.

doing this is cooled sufficiently rapidly to prevent it reaching the surrounding atmosphere. For comparatively low wattage lamps, the heat generated can be dissipated sufficiently rapidly to avoid a dangerous temperature rise on the outside of the fitting without making it unduly cumbersome.

The fittings at present on the market which carry the Board of Trade Mines Department certificate of suitability for use in the presence of certain vapours and gases are designed to meet these requirements. Such certificates are awarded after the testing authority has ascertained by examination and test that the fitting complies with the definition of a flameproof enclosure in B.S.S.229 with respect to the particular vapour or vapours for which the certificate is desired. These are divided into three groups: Group 1, Methane and Acetone; Group 2, Pentane and Petroleum Vapour; Group 3, Coal Gas. In the case of fittings for use in cellulose industries, which come under Group 1, the maximum permissible temperature rise on the outside of the fitting is limited to 60 deg. C.

In all cases certification is conditional on the testing by the manufacturers of each individual wellglass under hydraulic pressure, and on every replacement wellglass being cemented into the retaining ring. There is, however, some difference of opinion as to the methods which should be adopted in the testing of flameproof fittings particularly for temperature rise, also as to the best general characteristics of such fittings.

Experiments recently carried out have shown that cold cathode electric discharge tubes can be broken in a methane-laden atmosphere without causing ignition. In view of the low temperature at which these tubes run, it therefore seems possible that they may eventually be accepted as safe for use in some Group I situations, including cellulose spraying booths and shops. The electrodes would, of course, provide something of a problem unless arranged outside the danger area, but this would present no difficulty in booths. In the last few years great advances have been made in the production of powders which will fluoresce brilliantly under the ultra-violet radiation in mercury and neon-discharge lamps. Tubes internally coated with such powders operate at very high luminous efficiencies, of the order of 20 lumens per watt overall for combinations giving a suitable colour balance. It seems likely, therefore, that such discharge tube lighting with its high luminous efficiency and extended dimensions may prove a more satisfactory illuminant than the alternative tungsten lamp methods at present employed and to which reference has already been made.

There is little doubt that as the dangers associated with the use of ordinary equipment for the illumination of areas where inflammable materials are present become more widely appreciated, the official regulations governing equipment within the area will become more stringent. Where the illumination of the area cannot be accomplished from outside, flameproof equipment either with tungsten filament lamps or fluorescent discharge lamps is obviously the only solution to the problem. There are, however, many situations where it is practical to use external lighting, the fittings being in the open air, and when this is so such a method is generally the most satisfactory.

Fittings to resist the attack of corrosive atmospheres.

Installations in works employing acids or alkalis are often subject to corrosive attack. Chemical manure plants, dye works, plating and other metal treatment processes and gas works are examples of such situations. Equipment near the sea is also liable to corrosion due to the sea-spray-laden atmosphere.

It is difficult to give general rules for determining the best material for any situation because the shape of fitting required, cost and other details, may eliminate a material which is otherwise suitable

Porcelain and Vitreous Enamel.

Fittings not required to have elaborate optical systems for the redistribution of light can often be made in porcelain. Fig. 5 shows such a fitting in which a porcelain top holds a screw-neck flashed

Fig. 5. A porcelain topped enclosed opal globe fitting with screw neck.

opal globe. A rubber gasket between the top and the globe renders the whole fitting watertight and very satisfactory for use in any corrosive atmosphere. In this particular design the opal globe can be replaced by a vitreous enamel over-reflector and a clear wellglass. This gives better light control and the vitreous enamel (which can be regarded as a layer of glass on iron) is very resistant to all normally encountered corrosive atmospheres provided it is not chipped or cracked. As soon as it is damaged, however, the iron may be attacked and the fitting may rapidly deteriorate. Vitreous enamel is found in practice to be one of the best materials for this type of work for use as a diffuse reflector, and when held by means of a porcelain canopy a very satisfactory unit is obtained for use in corrosive atmospheres.

Specular Reflectors.

All specular reflectors for use in corrosive atmospheres must be protected as far as possible by means of a totally enclosed housing. For this reason one of the most satisfactory specular reflectors is silvered glass with a suitable protective backing, since the backing on one side and the clear glass on the other form a protection for the silver layer. One of the best methods is to coat the silver first with copper and then with lead. Fig. 6 shows a dispersive fitting with silvered glass reflector. The canopy and lampholder are made of porcelain.

Anodically oxidised and polished aluminium can be used as a specular reflector where the corrosive attack is not great, and, being very light and easily

Fig. 6. Porcelain top watertight fitting with silvered enclosed globe.

worked, it is a convenient material. Its use is increasing but it is doubtful whether it is so durable as properly silvered glass. Rhodium plating is very resistant but somewhat expensive.

Chromium plating on nickel has the advantage that all signs of normal deterioration can be washed away with soap and water; this applies also to stainless steel. Both these surfaces have a comparatively low initial specular reflection factor, and their use is therefore rather avoided. Table I. gives the specular reflection factors of the five materials discussed.

TABLE I.

Specular reflection factors of various materials to white light.

Material.	Reflection Factor.
Silvered glass	89%
Anodically oxidised and polished aluminium ...	70%
Chromium plate on nickel	61%
Stainless steel	61%
Rhodium	75%

Reflector Housings.

Apart from porcelain, which has already been discussed, several metals are used for reflector housings. The most common are iron, steel, copper, brass, lead-coated steel, and aluminium.

Iron and ordinary carbon steel rust in normal atmospheres and must be protected in some way. Suitable methods are painting and galvanising. Good stainless steel in a highly polished condition is, however, one of the most resistant of metals. In particularly bad situations a combination of moisture and acids (notably hydrochloric and acetic) may cause rust spots to develop, but in general this metal is likely to give good service.

Copper and brass do not corrode as rapidly as would be judged from their rate of discolouration. Both resist the attack of acids but not of alkalis, copper being better than brass.

Lead-coated steel will resist most types of corrosive attack and is very suitable where sulphuric acid fumes are present. It is essential that the lead coating is continuous, since any puncture in the lead will allow the corrosion to take place.

Aluminium and its alloys will corrode in marine or bad industrial atmospheres. Anodic oxidation increases the resistance of these metals, but does not make them completely immune.

The use of dissimilar metals in close contact can produce electrolytic action so severe as to accelerate considerably the corrosive effect of the atmosphere. Thus aluminium and copper in contact in a damp atmosphere will often cause this type of corrosion, and other examples are copper and iron, aluminium and tin, and iron and zinc. (Proc. A.S.T.M., 1935, Vol. 35, Part I., pp. 167-175. Report on Galvanic and Electrolytic Corrosion of Sub-Committee VIII. of the American Society for Testing Materials.)

Testing materials for corrosion is generally difficult, and often it is not possible to simulate local conditions or to devise a forced life test. Fig. 7, however, shows a sea spray tank in which samples of aluminium castings are undergoing corrosion tests. The tank is 6 ft. 8 in. by 4 ft. by 3 ft. deep and has about

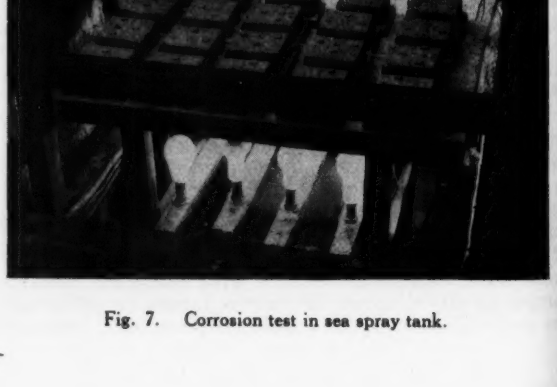

Fig. 7. Corrosion test in sea spray tank.

2 in. of water in the bottom. Into this water dip four atomisers which, when working, keep the whole tank filled with fine sea spray. The samples under test are kept warm by means of heating elements beneath them. These heaters are on continuously while the spray has one hour on and one hour off. Fig. 8 shows

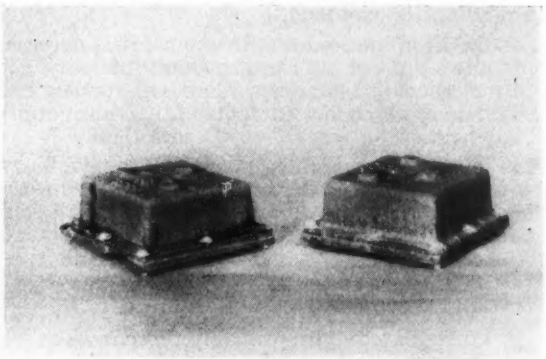

Fig. 8. Sample of aluminium castings after exposure in sea spray tank.

two samples taken from the tank after 2,500 hours. In the left-hand sample a bolt head has been corroded away completely. Such tests can only be comparative, of course, but by testing samples of known practical value a fair estimate of the possibilities of other samples can be obtained.

(b) Situations requiring special sources or arrangement of sources.

Artificial Daylight.

It seems probable that the difference in the apparent colour of objects when viewed by artificial and natural light has been noted by critical observers from the earliest times. Certainly such discrepancies have been widely known ever since the inception of current artificial light sources, and the recent development of the use of electric discharge lamps has provided examples of this phenomenon which are probably more striking and more widely commented upon than any previously accessible to the general public.

There are many industrial purposes for which ordinary forms of artificial light are unsuitable owing to the necessity for a colour rendering which is similar to that obtained in daylight, and there are many others where although daylight colour rendering is unimportant, differences in colour which are difficult to detect in normal artificial light must be rendered more obvious. Since the daylight appearance is generally considered satisfactory in such cases, any form of special light which simulates this more closely than ordinary artificial light is generally referred to as " artificial daylight," though it would probably be more correct to limit the term to lights under which daylight colour rendering is reproduced with some considerable degree of fidelity.

The method of obtaining a colour-matching light from tungsten lamps by means of glass filters or specially coloured reflectors, though widely employed, is not completely satisfactory where extreme accuracy and constancy is desired, since however good the filter or reflector may be, the system is still dependent on the tungsten filament lamp. The changes in the colour of the light emitted by the lamp during ageing and due to quite normal voltage fluctuations cannot be allowed for in the filter, and may produce sufficient difference in the quality of the artificial daylight to cause discrepancies in matching operations performed at different times. For situations requiring light sources which will give approximately daylight colour rendering to objects without, however, having to satisfy the most stringent requirements of colour-matching, such fittings can give very satisfactory results. They have the advantage of being the cheapest lighting system to instal capable of giving approximately daylight colour rendering.

It is possible that fluorescent discharge tube lighting may be found more suitable than colour-corrected tungsten filament lamps for many situations. Very good colour rendering can be obtained under correctly chosen combinations of tubes, with a very high luminous efficiency.

For the most critical colour-matching work the best source is a cold cathode carbon-dioxide discharge lamp. (Fig. 9.) Although its efficiency is low the lamp is almost completely independent of variations due to ageing or to mains voltage fluctuations, and avoids the use of filters and reflectors of special colour. Although the spectrum of the light from such a tube is essentially a line spectrum and therefore different in form from that of natural daylight, the lines are so closely spaced that both the colour of the source and the colour rendering of objects under this form of artificial daylight agrees extremely well with the result in the obscured north sky daylight usually employed.

Critical control of the gas pressure is essential for colour constancy, and this has been obtained automatically by means of a Moore valve operated by a solenoid connected in series with the electric supply to the tube. A fall in pressure causes an increase in the current flowing, raises an armature and exposes

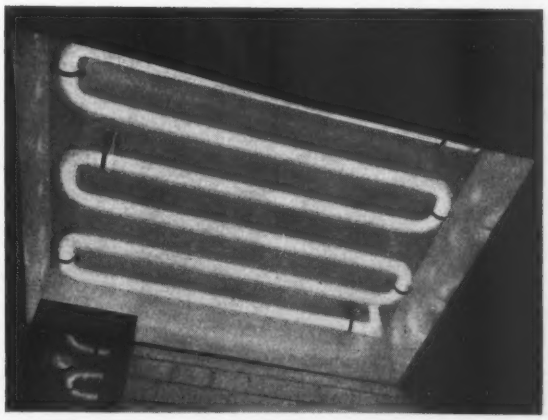

Fig. 9. Carbon dioxide discharge tube for artificial daylight.

the tip of a porous carbon cone normally immersed in mercury and through which fresh carbon dioxide is admitted until the normal current flows, when the cone is again covered. Mains voltage fluctuations affect the intensity but not the colour composition of the light, so that a constant colour is maintained under all circumstances. Fig. 10 shows a typical installation in a hosiery mill and under it the pairing

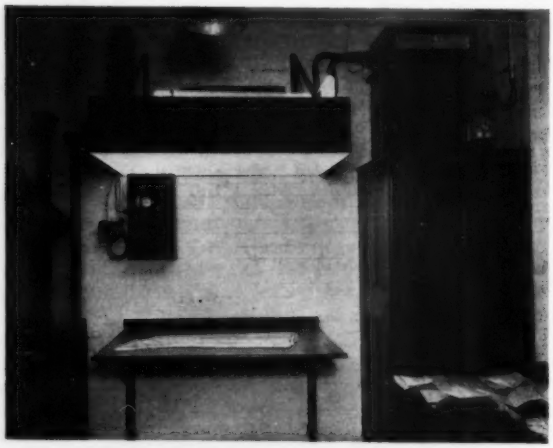

Fig. 10. A Cold Cathode carbon dioxide tube artificial daylight installation in a hosiery mill.

of stockings and matching with standard shades is carried out. This installation consists of 34 ft. of 45 mm. diameter tubing arranged in grid form, contained in a rectangular sheet steel reflector 4 ft. x 3 ft. and enamelled white inside. The bench is illuminated to an intensity of between 35 and 40 foot-candles, which has been found very satisfactory for colour matching operations. Such an installation involves a consumption of about 1,500 watts, corresponding to an efficiency of approximately 2 lumens per watt. While this is admittedly a low efficiency, it compares favourably with that obtained by the use of a 500 watt tungsten lamp unit employing the Lamplough double glass filter.

Discharge tube installations of this type are in use in paper mills, a leather cloth factory, dye works, a fur factory, and a cloth warehouse, in addition to hosiery mills. The smaller portable daylight unit illustrated (Fig. 11) operates on the same lines, and is useful where it is inconvenient to make all matching operations in one place.

The Lighting of Standards Rooms.

The great and increasing importance of accuracy in the large scale manufacture of machines of which uniformity of performance and interchangeability of parts is demanded, has given rise to a somewhat novel set of requirements in the illumination of the room in which accurate comparison with the master patterns and other measurements are made.

In the manufacture of modern aircraft engines elaborate precautions are taken to obtain constant conditions in such standards rooms. The rooms are built on foundations which are separated from those of the surrounding building, the walls are lined with a fibrous board behind which is a locked air space, the ceilings are of concrete similarly lined, the air is conditioned and kept at a constant temperature, the room is entered by way of an air-lock chamber, and daylight is excluded.

For the illumination of such rooms, it is necessary to provide a light of high and constant intensity, good diffusion, a colour quality which is psychologically cheerful, and which is accompanied by a minimum of radiant heat.

The rooms are generally about 300 square feet in floor area and 10 feet in height, and it is of interest briefly to consider the possible methods which could be adopted for their illumination.

(1) A direct system utilising enclosed ceiling fittings and tungsten filament lamps. To provide a sufficiently well diffused and evenly distributed light, probably three rows of four fittings at about 5-feet centres would be required. Twelve fittings, each equipped with a 200-watt lamp, would provide a service illumination of about 28 foot-candles, which is approximately that chosen by executives of the first works in which an installation of the type to be described was made.
Some disadvantages of such a scheme of ceiling fittings are that a total of 2,400 watts of

Fig. 11. Portable artificial daylight unit employing carbon dioxide discharge tube.

tungsten lamps would give considerable radiant heat, the intensity and colour quality of the light are not constant, and so many sources concentrated on a low ceiling of small area would give a rather glaring effect.

(2) An indirect system from pendants, cornice, or brackets would avoid the glare, but would

considerably increase the necessary wattage, and, consequently, the heating effect. Further, the somewhat "dead" effect of indirect lighting would be experienced unless supplementary direct lighting were added.

(3) A large laylight, or system of smaller laylights on the ceiling would be practicable on the score of appearance, brightness, and diffusion, but would give rise to at least as much undesirable heating as the direct ceiling fitting system. In common with the previous systems, utilising tungsten lamp sources, it would not provide completely constant colour and intensity.

(4) High-voltage fluorescent discharge tubes possess several advantages for standards room lighting. Being naturally extended in form, and of low surface brightness, fluorescent tube lighting can be applied direct to the white ceiling of the room without any extra reflector or diffusing medium, and the light provided is excellently diffused, comparatively shadowless and of even intensity. Colour composition can be varied by means of mixing the light from different types of tube, and experiment resulted in the selection of a combination consisting of two (white) mercury-filled tubes and one (pink) neon-filled tube. This combination gives reasonably good colour rendering, is cheerful, and proves satisfactory for the reading of fine micrometer graduations. Colour and intensity constancy is achieved by providing a tapped choke in series with the primary of the transformer feeding the mercury-filled tubes, these being underrun initially and brought up by alteration of choke tappings at intervals during life. The neon-filled tube has a practically constant light output throughout its life, and hence needs no such adjustment.

Because of the high intrinsic efficiency (of the order of 18 lumens per watt for the combination of tubes chosen) and the absence of diffusing medium losses, the total wattage necessary for a given intensity on the working plane is only about half that necessary with tungsten lamps in suitable diffusing fittings or laylights. This, of course, reduces considerably the heating effect of the sources.

The first installation of this type in a standards room proved very satisfactory in practice and others have followed. The intensity provided varies between 16 and 28 foot-candles in different installations, and though the initial cost is admittedly high in comparison with other forms of standards room lighting, the advantages of the fluorescent tube lighting are considered to outweigh consideration of capital cost in view of the extremely important and exacting nature of the work.

Fig. 12 shows a typical installation in a standards room. The equipment includes five parallel lines, each consisting of three triple tube units arranged end to end and joined by common electrode boxes. The length of tube visible between electrode boxes is about 8 ft. 6 in. Each triple tube unit absorbs approximately 130 watts and operates at an overall

Fig. 12. Lighting with fluorescent discharge tubes in an aircraft gauge room.

efficiency of about 18 lumens per watt. The maximum surface brightness (on the mercury-filled tube) is of the order of one candle per square inch.

As the mercury-filled tubes operate at one current density and the neon-filled tubes at another, two sets of high-tension transformers are necessary, but several individual lengths of one type of tube are connected in series. Thus the number of high-tension cable runs and transformers is reduced. Transformers and tapped chokes are situated on the roof of the room and the low-tension supply is usually arranged on a three-phase system. Stroboscopic effects are thus reduced, and the slight effect remaining appears to be quite negligible in practice.

Lighting for the Inspection of Polished Surfaces.

The inspection of polished surfaces is a good example of a process the lighting of which must be carefully controlled in direction, and in which the arrangement and design of the light source is generally more important than the type of illuminant employed. A fundamental property of a polished surface is that it is primarily a specular reflector. A beam of light falling on to a polished surface is reflected according to certain well-defined laws with very little diffusion of the light. The better the reflector, the less the diffusion.

For this reason it is difficult to see a polished surface except by reflections in it. This is illustrated by the photographs, Figs. 13, 14, and 15. Fig. 13 shows a silver bowl mounted on a white cloth. Many objects in the room can be seen reflected in the bowl. Fig. 14 shows the same bowl inside a whitened box under a vertical illumination of 17 foot-candles. The bowl has taken on the surrounding brightness so that nearly all contrast has gone. In Fig. 15 the white

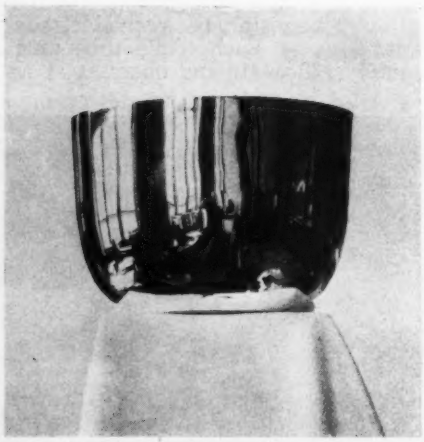

Fig. 13. Silver bowl mounted on white cloth.

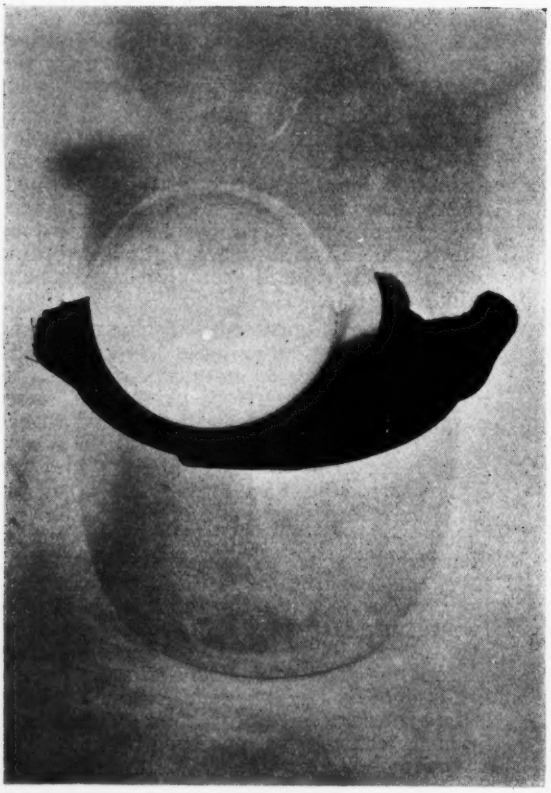

Fig. 14. Silver bowl in white box. Vertical illumination 17 foot candles.

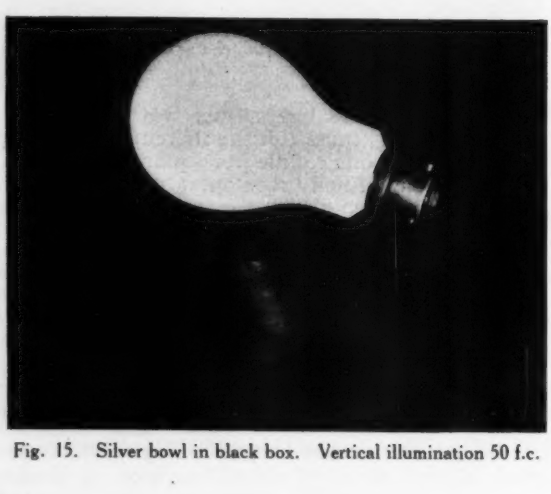

Fig. 15. Silver bowl in black box. Vertical illumination 50 f.c.

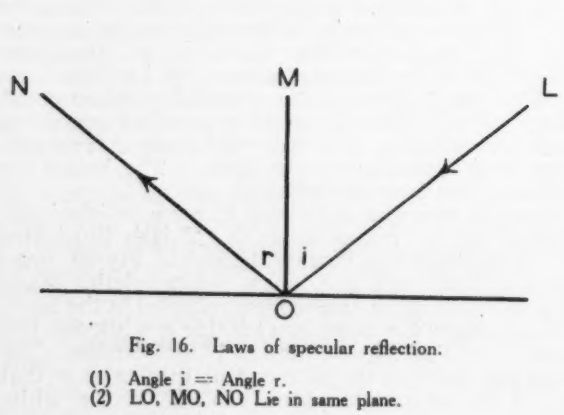

Fig. 16. Laws of specular reflection.

(1) Angle i = Angle r.
(2) LO, MO, NO Lie in same plane.

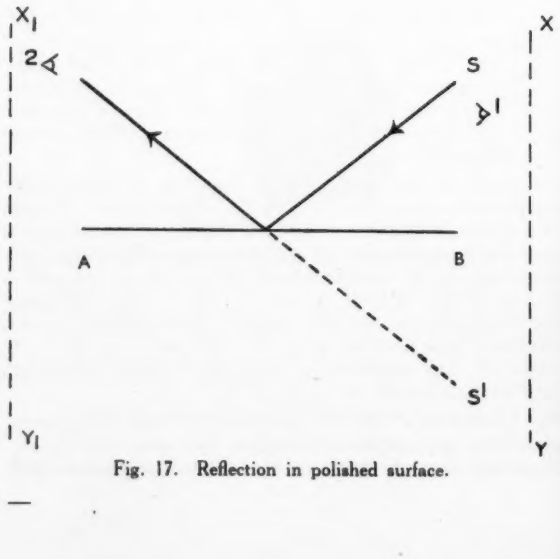

Fig. 17. Reflection in polished surface.

surround is replaced by black velvet, and although the illumination is increased to 50 foot-candles, the bowl has again almost completely disappeared. The opal lamp resting in the bowl presents much the same appearance, however, both in Figs. 14 and 15.

The laws governing the reflections are, of course, that the angle of reflection is equal to the angle of incidence and that the incident and reflected rays lie in the same plane as the normal to the surface at the point of reflection (Fig. 16).

If a beam of light is directed on to a perfectly polished metal sheet, the only light which will be visible in the sheet will be a reflection of the background or surrounds except where a definite image of the lamp can be seen.

In Fig. 17 AB is the polished sheet and the light is falling upon it from the source S. An observer at position (1) will only see the reflection of the background X_1 Y_1 but at position (2) it may be possible to see the background X Y and a sharp image (S^1) of the light source S. This result is used to detect scratches on tin-plate and similar materials. A scratch, being a comparatively deep furrow in the surface, will reflect light back in a direction roughly at right-angles to its length; Fig. 18 shows a sheet of tin-plate lit to reveal the scratches. This type of lighting also brings out an interesting " tree-like " crystalline structure in the metal.

Bloom or tarnish on a polished metal surface is apparent in its diffusing effect, and if the reflection of a black object is viewed in the sheet the tarnish becomes obvious. In examining for this defect, therefore, the sheet should be strongly illuminated, but in such a manner that no reflections of light sources reach the observer, who views the reflection of a black background in the surface. Untarnished parts of the reflector appear black, but the tarnish reflects light into the observer's eyes. Fig. 19 illustrates this. (Kenworthy and Waldram, Journal of the Institute of Metals, Vol. LV., No. 2, 1934.)

Fig 20 shows a useful method of examining bruises in a polished sheet. A grille is placed in front of a uniformly illuminated panel and the reflection viewed in the sheet under test. Variations in smoothness of the surface reflect a black strip where normally a white line should occur and vice versa. The same apparatus can also be used to detect very small irregularities by the ragged appearance of the strip images. Such an optical system will show the presence of buffing marks, etc. (Waldram, Illum. Eng. (London), Vol. XXVII, No. 5, May 1934, p. 163; also Ketch, Sturrock and Staly, Trans. III., Eng. Soc. (America), 1933, p. 57). In tinplate examination it is important to discover any places where " pitting " has taken place in the tin coating. These are best revealed by viewing in the sheet the reflection of a large white surface as in Fig. 21. The iron base metal shows through in small black spots where it fails to reflect light to the same extent as the tin plating. It is often difficult to apply the methods just described to practical large-scale working without introducing a double sorting scheme on the conveyor belt or some similar device; but where the

Fig. 18. Sheet of tin plate lit to reveal scratches.

flaws to be detected are limited in number it is sometimes possible to arrange the lighting in a simple manner. Fig. 22 shows the arrangement which has been adopted in a tinplate works.

A domed, light grey ceiling and wall is illuminated by an angle type reflector which also provides a strongly directional lighting on the tinplate sheets. This directional lighting is sufficiently intense to show bad scratches even against the light background

Fig. 19. Examination of tarnished sheet.

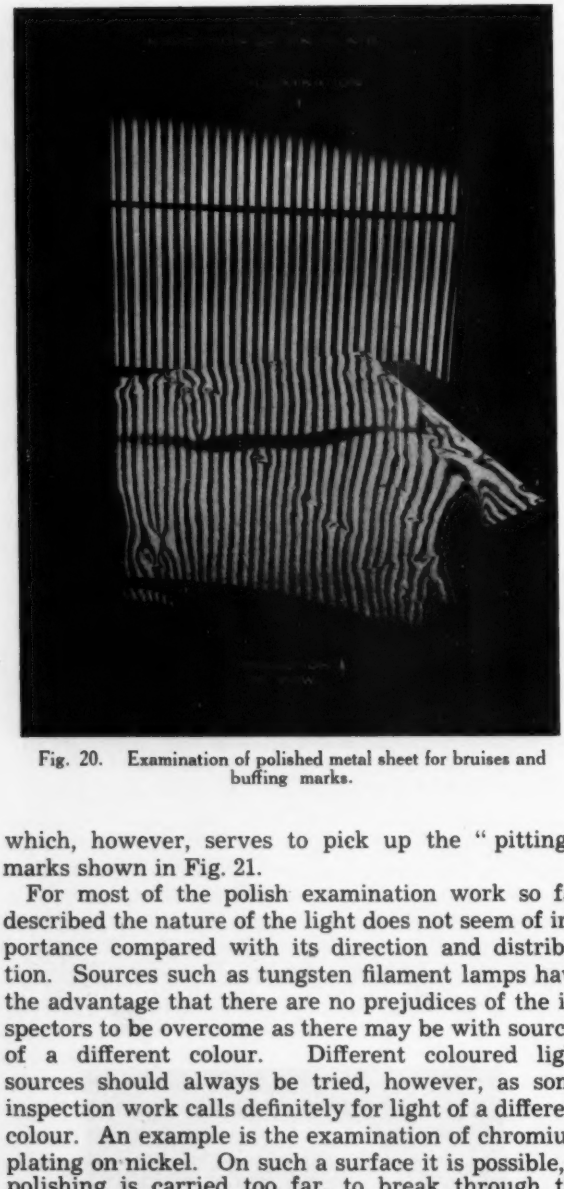

Fig. 20. Examination of polished metal sheet for bruises and buffing marks.

which, however, serves to pick up the "pitting" marks shown in Fig. 21.

For most of the polish examination work so far described the nature of the light does not seem of importance compared with its direction and distribution. Sources such as tungsten filament lamps have the advantage that there are no prejudices of the inspectors to be overcome as there may be with sources of a different colour. Different coloured light sources should always be tried, however, as some inspection work calls definitely for light of a different colour. An example is the examination of chromium plating on nickel. On such a surface it is possible, if polishing is carried too far, to break through the chromium surface to the nickel layer. The nickel has a yellowish tinge compared with the chromium, and if a light blue background is viewed by reflection in the sheet, the break-through is fairly easily visible. A suitable light source is the high-pressure mercury vapour lamp, which is better for the purpose than plain tungsten filament lighting and several times as efficient as tungsten filament lamps with suitable blue filters.

Satisfactory lighting for inspection can only be determined after experiments have been made, paying particular attention to the local conditions,

Fig. 21. Sheet of tin plate lit to reveal pitting.

but the lines of attack described above will often be found to assist materially.

In conclusion, the authors would like to thank their colleagues for their assistance and the Directors of The General Electric Co., Ltd., for permission to publish this paper.

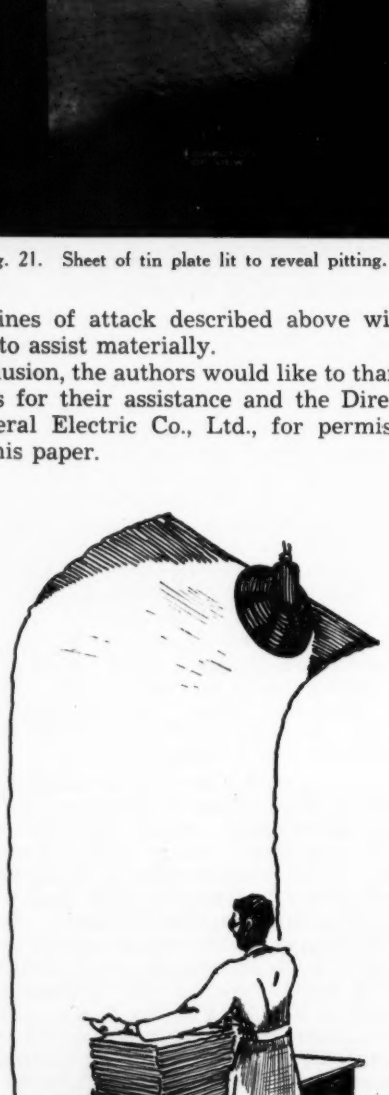

Fig. 22. Method of inspection of polished metal sheets.

DISCUSSION

Dr. S. ENGLISH expressed the pleasure of the Illuminating Engineering Society in holding this meeting with the Association of Supervising Electrical Engineers to discuss special aspects of industrial lighting. The lighting of factories had become much more important than in the past, and it was expected that the Home Office would be framing requirements on this subject before very long. Apart from the special problems dealt with in the paper, there was an enormous field for improvement in the general lighting of factories. Such joint meetings as these, which would serve to bring illuminating engineers and those concerned with the management of factories in contact with each other should lead to better lighting conditions for those who had to spend their lives in industrial work. The Illuminating Engineering Society had recently set up a special Industrial Lighting Section in order to study the real essentials of good industrial lighting, and it would be of the greatest assistance if the members of the Association would bring their problems to the notice of the Society in order that they might be studied in a practical as well as a scientific manner.

The Society welcomed members of the Association to its meetings, and especially at meetings of the Industrial Lighting Section, at which they would be very welcome—the more so if they cared to join the Section.

Glancing at the paper from the point of view of the illuminating engineer, he formed the impression that the principles laid down would meet with general agreement, but in the application of those principles there seemed room for some difference of opinion. For instance, the suggestion of lighting through a glass window in the case of rooms where there was an explosive atmosphere could not be very efficient—if only for the reason that one could not always be sure the window was clean. Getting outside such a room in order to light it seemed to him rather to shirk the real issue. This problem should be met by the use of fittings designed to be flameproof. There were a number of such fittings available which were reasonably efficient, certainly more so than the method of lighting from the outside.

In regard to daylight lamps, of which several types had been described, the British Standards Institution had considered the formulation of a specification for a lamp using a pale blue correcting screen—nothing like the usual daylight lamp. The authors did not mention this new device. In Committee it had been said there was a real demand for an inspection lamp of this type, and he would like the authors' views as to whether the pale blue correction was of assistance in inspection work.

Mr. E. W. MURRAY, commenting on the statement in the paper that "fittings of the non-flameproof type might be used just outside a partially enclosed dangerous area," said the authors could not have seen the cellulose regulations. Under these regulations fittings of the type mentioned must be at least twenty feet away from any cubicle of the kind mentioned. These particulars were given in the Statutory Rules and Orders, 1934, No. 990, and were known as "The Cellulose Solutions Regulations, 1934."

Another feature in connection with flameproof fittings was the absence of suitable reflectors and the consequent disadvantage of glare owing to the small angle of cut-off. The new B.S.I. specification for flameproof fittings, he understood, specified a reflector to give the same usual angle of cut-off as for industrial reflector No. 1. (B.S.I. No. 232-1935.)

Mr. G. JELLEY, referring to the method of lighting cubicles from the outside, suggested it might be possible to fix the lamp on the outside of the roof in such a way that it was part and parcel of the roof. In that case, the result would be the equivalent of a direct lighting fitting.

Mr. J. PENNY enquired why copper was not used more for the types of fittings described and demonstrated by the authors. He had never seen copper used for floodlights or reflectors in corrosive atmospheres and had wondered why, seeing that copper was reasonably cheap in comparison with some of the other metals used.

Mr. J. S. Dow remarked that the authors had mentioned discharge tubes utilising flourescent powders. He had recently seen similar lamps using tubes of fluorescent glass, apparently with excellent results and with, possibly, greater permanence.

The authors had referred to artificial daylight which involved accurate correction of the light for colour-matching purposes, with a corresponding high absorption of light. He wondered whether they had formed an opinion as to the desirability of using slightly corrected units, giving a similar light visually to daylight, which could be achieved with a relatively small absorption. Some people contended that such a light was beneficial to the eyes, especially if the inspection of detail at close quarters were involved; it had also the advantage of readily mixing with natural light, in workrooms where both forms of light were often in use simultaneously.

Mr. F. C. ALLDRED asked whether it was necessary to machine the faces of the flanges of flameproof apparatus such as the authors had demonstrated, and also to coat the faces with grease or vaseline. He mentioned a case of a flameproof lamp placed underneath a petroleum oil pipe-line. Oil had leaked from a valve completely swamping the top of the fitting and had dissolved the vaseline in the joint. The enclosure filled with oil. The effect of the heat of the lamp had been to give the impression that the outside of the lamp had been given a coat of varnish.

Mr. R. O. ACKERLEY, commenting on Dr. English's remark that it was inefficient to light from the outside of cubicles, said the question was whether this, in the circumstances, was inherently the best method. In cases where there was a north light and the light from the lamp outside came through at the same angle as daylight did, it was possible to get

very efficient lighting by having the lamps outside but close against the glass of the roof. He rather questioned whether the flameproof lamps available were all that was to be desired. In his view they were clumsy and cumbersome and heavy in proportion to their wattage, and it was of practical importance to have a high wattage flameproof lamp. A 200-watt flameproof fitting weighed 15 lb. or 20 lb. and cost about £7. He agreed with Dr. English, however, with regard to the advantages of a pale blue "daylight" inspection lamp, for there were many cases where such a lamp would be extremely useful, especially where an extremely accurate colour discrimination was not required.

Referring to the remarks by Mr. Murray, he said the trouble with Government Departments was that they could not make up their minds what they wanted. He assured Mr. Murray that special lighting installations had been referred to the Factory Inspector and had been passed, and he also enquired of Mr. Murray whether he could say that the 30 ft. regulation he had referred to earlier applied in the case of a cubicle fitted with forced draught where the finished cellulose articles were not dried off afterwards. He had been given to understand that provided there was no drying off and there was evacuation by forced draught, fittings could be placed within 7 ft. Speaking of the use of copper, Mr. Ackerley said there were fittings available with copper housings, but the difficulty was with the reflectors because copper could not be vitreous enamelled. Finally, Mr. Ackerley said he had never heard of grease being used for flameproof fittings, and it was not normally recommended.

Mr. D. OATES, commenting on the explosion experiment carried out by the authors, pointed out that the fitting in this case was in a non-explosive atmosphere, and asked what would have happened had the surrounding atmosphere in the room been explosive.

Mr. P. S. BARTON asked whether in the event of fittings being made part of the roof, as had been suggested by one speaker, it could not be said, so far as the regulations were concerned, that the fitting was part of the room or cubicle and therefore, in effect. was *inside*. As a matter of fact this question had arisen, but whether the Home Office approved or not he was not aware.

Mr. E. W. MURRAY replied that the only dimension mentioned in the Cellulose Regulations was 20 ft. There was nothing about 7 ft. or any other distance (see 5a page 3 Cellulose Regulations, 1934). What happened was that where an open lamp was found within a spraying cubicle the occupier was told that it was wrong and advised accordingly. He knew of cases where occupiers had more or less refused to change the position of the lamps—but such an attitude might result in serious consequences in the event of an accident, involving, perhaps, censure at a Coroner's Court.

Mr. OATES said he would like an explanation of why the flame when exploded in the flameproof fitting—as demonstrated by the authors—was cool when it reached the outside.

Mr. J. J. SMITH asked what was the efficiency of the daylight lamp which had been exhibited and how long did it take to reach its full illumination.

Mr. E. H. BRODIE, commenting on the statement in the paper that recent experiments had shown that cold cathode electric discharge tubes could be broken in a methane-laden atmosphere without causing an explosion, asked whether this also applied to other explosive mixtures.

Mr. A. S. H. BRACKENBURY mentioned the possible use of fluorescent powders for tubular sources used for photographic purposes, and asked whether there had been developed any method of using these tubes in that way.

Mr. F. C. SMITH said that it was extraordinarily difficult when an atmosphere of mixed inflammable gases was under consideration to deduce from the composition of the mixture what the ignition temperature would be. The whole question of the ignition of gaseous mixtures was very complex. Factors other than composition, such as the shape of the vessel in which the gases were enclosed, the nature of the walls, etc., would have a considerable effect on the ignition temperature and the propagation of flame through the mixture.

The CHAIRMAN, in bringing the discussion to a close, referred to researches carried out by the Electrical Research Association into the heating of flexible cables used for large wattage lamps. As a result, a number of suggested improvements in the construction of the lamps and fittings were recommended which had the effect of reducing appreciably the very high temperatures which existed in the flexible connections. There has been difficulty in certain cases, in getting makers to apply the results of these researches, and many fittings were still designed in such a way that they did not avoid such high temperatures. Because of this some effort had been made to get the cable makers to try to produce flexible cables which would stand very high temperatures, but this they did not seem to be very anxious to do. The E.R.A. had also carried out experiments into the inflammability of various dusts in relation to the temperatures of lamp fittings. He had been somewhat surprised that no mention was made in the paper of the work done by the Electrical Research Association, and it would be interesting to know if it had been found useful in industry.

Mr. S. ANDERSON, who replied to some of the points raised in the discussion, said that, while appreciating

that much valuable work was done by the E.R.A. the authors were not familiar with the details of the explosive dust experiments mentioned by the chairman and had confined themselves to matters with which they were more familiar. With regard to official regulations, he said he was under the impression that there were very few dusty situations where a special type of fitting was insisted upon by the Home Office Inspectors. There was a tendency in flour mills and other dusty works to use low wattage lamps, but whether that was done from the point of view of economy or safety he did not know. The fittings manufacturers were fully aware of the cable deterioration brought about by high temperature, and were doing their best to reduce the temperature rise of reflectors, but it was extremely difficult to design a fitting of reasonable proportions and at a moderate price in which the temperature rise in service was very small. At the same time, certain types of industrial reflector were available in which the cable temperature was within the maximum recommended by the C.M.A.

In reply to Dr. English, he admitted that some light was lost when the fittings were situated outside glass windows. At the same time, where large areas had to be lighted in a flameproof manner, the limitation in size of the flameproof fittings so far available and their high cost had in such cases resulted in the choice of outside lighting, where advantage could be taken of the high efficiency of high-wattage tungsten and mercury discharge lamps. Owing to the heavy canopy and well glass construction of flameproof fittings, the efficiency of these was probably but little better than that obtained with an external lighting system.

In further reply to Dr. English he said that pale blue "daylight" lamps were available and he believed these had proved satisfactory for some inspection operations. While the use of weak blue glass filters had proved satisfactory in certain cases, these would not be suitable for really accurate colour matching operations and the critical inspection of colours for which the discharge tubes referred to in the paper were intended.

In reply to Mr. Murray, he said in several factories this method of booth lighting by fittings near the booth, though evidently not complying with regulations, had been approved and there seemed to be no trouble with it. There was no glare from a lamp outside the booth unless the operator turned and looked directly at it, and the possibility of objectionable reflected glare from the work in hand was ameliorated by the frosted glass front used in the fitting shown. (Mr. Murray indicated his dissent from this.) Flameproof fittings were already available with dispersive reflector skirts giving the cut-off called for in B.S.S. 232. As to Mr. Jelley's remarks, he said there had been cases where fittings were built more or less into the roof, and he would be interested to hear if Mr. Murray could express any authoritative opinion as to the safety of such an arrangement where cellulose spraying was undertaken. It was quite true, as Mr. Mainer had said, that the portable daylight lamp demonstrated was not fitted with a Moore valve, but utilised an impregnated stick which when heated by a surrounding resistance wire liberated carbon dioxide. The Moore device was only suitable for the larger (fixed) installations.

As to the use of grease for the joints of flameproof fittings mentioned by Mr. Alldred, while such treatment might render the fittings more or less gastight, this was not a practical solution. As mentioned in the paper, flameproof fittings were designed in such a way that assuming an explosion took place inside, this would not ignite any inflammable substance likely to be present outside the fitting. To obtain a gap of the order of 0.01 inch it was necessary to machine the flange faces.

Mr. OATES contended that as there was an ignitable gas inside the fitting it could not be cooled by the time it passed through the gap.

Mr. ANDERSON said he found some difficulty in answering Mr. Oates because he had not been concerned in any direct measurement of the temperature of the flame inside or outside a flameproof fitting, but it seemed to him that in passing the small gap between the flanges the flame would lose heat, and, given a sufficiently wide flange, it must be quenched altogether. Experiments had shown that when the flameproof fitting was actually surrounded by an explosive mixture, on causing an internal explosion, there was no ignition outside, as had been demonstrated, and he attributed that to the cooling or quenching of the flame in passing through the gap.

Continuing, Mr. Anderson said that the "daylight" lamp with a discharge tube, which had been demonstrated, took a minute or two before it attained its correct colour when first switched on after not having been in use for a long time, but there was no such period of delay, as had been suggested might be the case by Mr. J. T. Smith, if it were switched on and off at short intervals. The efficiency of these carbon dioxide tubes was about 2-l/w., which compared favourably with the efficiency of other lamps giving a real approximation to daylight.

In reply to Mr. Brodie, he said the experiment referred to related particularly to conditions in coal mines, and the tubes had not yet been tested in the presence of other gases. The test was not in any way an official one. He agreed with Mr. F. C. Smith as to the difficulty of determining the conditions in which an explosive mixture might ignite, and it was particularly interesting to hear that the shape of the vessel affected the result.

Mr. W. R. STEVENS, replying to some other points, said that copper was largely used for floodlights and similar fittings. He believed that fluorescent powder was generally superior to the fluorescent glass mentioned by Mr. Dow. It was cheaper and resulted in a higher l/w. efficiency, whilst it was easier to get a wide range of colours with powders. As to the use of fluorescent powders for photographic pur-

poses, he thought they might be found useful for that work. The smallness of the heating effect of these light sources compared with that of filament lamps should prove valuable.

In reply to Mr. F. C. Smith, he said the authors were primarily involved at the moment in complying with the conditions laid down by the authorities, and they were not presuming to lay down conditions of temperature, etc. Therefore, when speaking of 60° C. as the maximum temperature rise in a fitting, it was not because they necessarily thought that to be a satisfactory maximum but because it was the value sponsored by the authorities.

Referring to the explosion demonstration which had been carried out and the challenge of Mr. Oates as to what actually took place, Mr. Stevens said it was not claimed that this experiment reproduced exactly working conditions, but he believed in the explanation that the flame was cooled, and suggested it was due to adiabatic expansion. It was the cooling of the flame between the flanges which made the fitting proof against external explosion.

The Illuminating Engineering Society is not, as a body, responsible for the opinions expressed by individual authors or speakers.

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